APPENDIX L
Suggested Analytical Criteria for Category II and III Packages

The Nuclear Regulatory Commission and Lawrence Livermore National Laboratory have developed extensive guidance for establishing analytical criteria for structural evaluations of Category I content package containment systems. However, little guidance has been developed in establishing analytical criteria for structural evaluations of Category II and Category III content package containment systems. As a result, this has lead to costly uncertainties by structural design engineers and analysts as to what evaluation criteria is acceptable to the certification authority.

Although the ASME BPVC has been specified for packaging containment system construction by current packaging standards outlined in various NUREGs for Category II and III packages, these specified ASME BPVC sections and subsections are based on “design by rule”. As explained in Appendix K, the ASME BPVC “design by rule” equations are generally only appropriate for designing components for internal pressure under normal operating conditions. Also, Subsection ND[L-1] and Section VIII, Division 1[L-2] of the ASME BPVC do not address accident conditions. Therefore, structural design engineers and analysts are left to develop and defend structural evaluation analytical criteria for packaging designs that are meant to be less costly than a Category I package.

In the past, another approach has been to use analytical criteria from Subsection NB.[L-3] However, Subsection NB analytical criteria are based on vessels constructed to much more restrictive criteria and do not address some of the fabrication and material options in Subsection ND or Section VIII, Division 1. As a result, Section 2.5 of this safety guide suggests analytical criteria for demonstrating acceptable structural performance of Category II and III content NNSA packages. The bases for this guidance is as follows:

1. For Category II content packaging constructed to Subsection ND requirements, the acceptance criteria and load combination guidance can be considered to be the Design Basis as defined in ASME BPVC, Section III, Subsection NCA,[L-4] NCA-2140.

2. For Category III content packaging constructed to Section VIII, Division 1 requirements, the acceptance criteria and load combination guidance can be considered to be the application of Paragraphs U-2(d) and U-2(g). Paragraphs U-2(d) and U-2(g) together permits the engineer to design components in the absence of rules in Section VIII, Division 1.

In the case of Category II content package containment systems, the guidance is based on the stress criteria provided in ND-3320. In the case of Category III content package containment systems, the guidance applies the analytical criteria from Subsection NE[L-5] and is based on NNSA precedents from previous certifications. In previous certifications, it was demonstrated that the analytical criteria for demonstrating acceptable structural performance based on Subsection NE provided sufficient assurance of packaging safety for packages constructed to ASME BPVC, Section VIII, Division 1 requirements.

In demonstrating the performance of containment systems for packages of the three content categories, the design stress intensities, and maximum allowable stress values, the various sections and subsections of ASME BPVC will be different for the same material. In general, one will find that the allowable stress intensities for Subsection NB and NG[L-6] (Class 1) materials are higher than Subsection ND, NF,[L-7] and Section VIII, Division 1 (Class 2 and 3) materials. The ASME basis for this is that Subsection NB and NG materials, fabrication, welding, and examinations are much more restrictive and both require "design by analysis" and use of the maximum shear stress theory of failure. It should be noted that Subsection NB and NG use the term "maximum design stress intensity value", whereas Subsection ND, NF, and Section VIII, Division 1 use the term "maximum allowable stress value". The reason for this difference is that the maximum design stress intensity value and maximum allowable stress value are determined differently and are based on different safety factors. As a result, the determination of design stress intensity is generally based on a safety factor of 3 on the ultimate strength of the material at room temperature. For Subsection ND, NF, and Section VIII, Division 1, the material maximum allowable stresses are determined based on a safety factor of 3.5 on the ultimate strength of the material at room temperature.

As an example of the application of these allowable values for demonstration of acceptable performance, consider a component manufactured for Type 304 stainless steel manufactured to ASME SA-240 requirements. The ASME values for ultimate strength and yield strength are 75 ksi and 30 ksi, respectively, from ASME BPVC Section II,[L-8] Part D for all classes of materials. As shown in Table L-1, the design stress intensity value (Class 1) and the maximum allowable stress (Class 3) for this material is the same value of 20 ksi at 100 °F. Also, by the guidance provided in Section 2.5 for evaluation of Category III content packaging constructed to ASME BPVC Section VIII, Division 1 requirements, Subsection NE (Class MC) "design by analysis" methods can be used. As such, the maximum allowable stress for this case is 22 ksi at 100 °F.

It should be noted that three different sets of allowable stresses for HAC evaluations of Category III content packages are provided. These three sets of allowable stresses account for the design of the component and type of evaluation performed as permitted by Subsection NE. In the case designated as “Elastic Analysis” in Table L-1, these values are Level D Service Stress limits for elastic analysis of solid rectangular sections where the structure is integral and continuous. In the case of inelastic analysis (designed as “Inelastic analysis” in Table L-1), the Stress limits are based on 85% of the value permitted in ASME BPVC, Section III, Division 1, Appendices,[L-9] Appendix F. In the case designated as “Not Integral” in Table L-1, these values are based on plastic analyses where the structure is not integral or continuous and/or at partial penetration welds. Also, it should be recognized in weld regions that the weld joint efficiencies (quality factors) for weld inspections should be accounted for.

Table L-1. Example of Material Allowables from NNSA Guidance (SA-240)

Allowable stress and classification		Category I content[a]	Category II content[b]	Category III content[c]		
NCT	P_m[d]	20 ksi	20 ksi	22 ksi		
	P_m+P_b[e]	30 ksi	30 ksi	33 ksi		
	P_m+P_b+Q[f]	60 ksi	No limit	66 ksi		
HAC				Elastic analysis[c]	Inelastic analysis[c]	Not integral[c]
	P_m	48 ksi	40 ksi	44.7 ksi	44.6 ksi	30 ksi
	P_m+P_b	72 ksi	48 ksi	66.9 ksi	44.6 ksi	45 ksi

Notes

[a] ASME BPVC, Section III, Division 1, Subsection NB.

[b] ASME BPVC, Section III, Division 1, Subsection ND.

[c] ASME BPVC, Section III, Division 1, Subsection NE.

[d] P_m is defined as the general primary membrane stress.

[e] P_b is defined as the primary bending stress.

[f] Q is defined as the secondary stresses.

As shown above, the allowables for NCT for Category I and II content packages are the same but are slightly higher for Category III content packages. For HAC, the allowables for Category I are higher than for Category II and Category III. On the surface, Table L-1 would indicate that, for Category II and III content packages, the containment system needs to be more robust. However, this apparent increase in robustness must be kept in perspective. Category II content package construction requirements are much less restrictive (e.g., all welds do not have to be full penetration). Category III package construction requirements are even less restrictive. As a result, there is more flexibility in packaging construction and the quality requirements are much lower, resulting overall in a more economical package.

At present, neither Subsection ND or Section VIII, Division 1 have any rules for fatigue evaluations of components. As such, it is suggested that the rules of ASME BPVC, Section VIII, Division 2,[L-10] Paragraph AD-160 or ASME BPVC, Section III, Division 1, Subsection NE, NE-3221.5 be applied.

References

L-1 ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection ND, New York, New York, 2001.

L-2 ASME, *Boiler and Pressure Vessel Code*, Section VIII, Division 1, New York, New York, 2001.

L-3 ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection NB, New York, New York, 2001.

L-4 ASME, *Boiler and Pressure Vessel Code*, Section III, Subsection NCA, New York, New York, 2001.

L-5 ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection NE, New York, New York, 2001.

L-6 ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection NG, New York, New York, 2001.

L-7 ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection NF, New York, New York, 2001.

L-8 ASME, *Boiler and Pressure Vessel Code*, Section II, New York, New York, 2001.

L-9 ASME, *Boiler and Pressure Vessel Code*, Section III, Division 1, Appendices, New York, New York, 2001.

L-10 ASME, *Boiler and Pressure Vessel Code*, Section VIII, Division 2, New York, New York, 2001.